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(56) Documents cited
EP 0228743 A1 EP 0228742 A1 EP 0123350 A1
EP 0089084 A1 WO 89/09501 A1 WO 88/01444 A1
WO 87/01517 A1

(58) Field of search
UK CL (Edition K) H1Q QBE QJA QJH QKA
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(54) Antennas and method of manufacturing thereof

(57) An antenna array is fabricated from an upper plate 1 consisting of an array of stepped horn elements 3 and a lower plate 2 comprising a waveguide structure 5.

The two plates are attached together by means of heat welding or solvent welding. In the case of heat welding the lower plate 2 is provided with a pattern of ribs (11, Figs 6 and 7) and the upper plate 1 is provided with corresponding troughs and grooves, the material of the ribs being caused to flow into the troughs following application of heat to the interface to the two plates, thus causing the two plates to become attached.

In the case of solvent welding, the rib and trough formations are omitted. The mating surfaces of the plates are brushed with dichloromethane and brought into abutment, causing the plates to become attached together.

Subsequent to attachment, the structure is immersed in an electroless copper plating bath so that a thin film of copper is deposited on the exposed surfaces of the structure. Thus any imperfections in the flatness of the mating surfaces which would otherwise cause undesirable leakage of microwave radiation are effectively compensated for by the copper film. Alternatively silver or aluminium may be used to plate the structure.

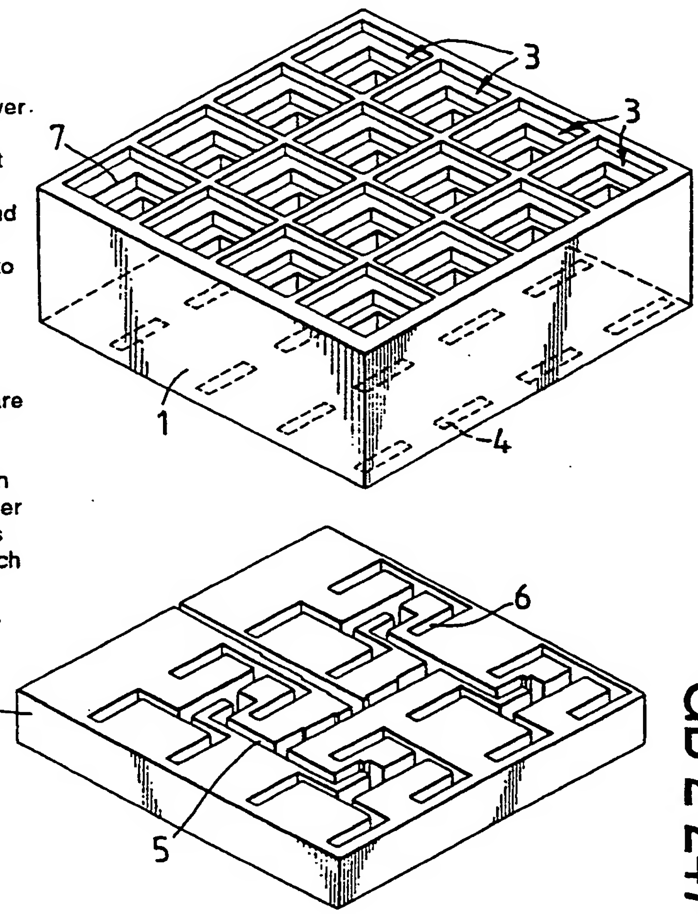

FIG.1.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

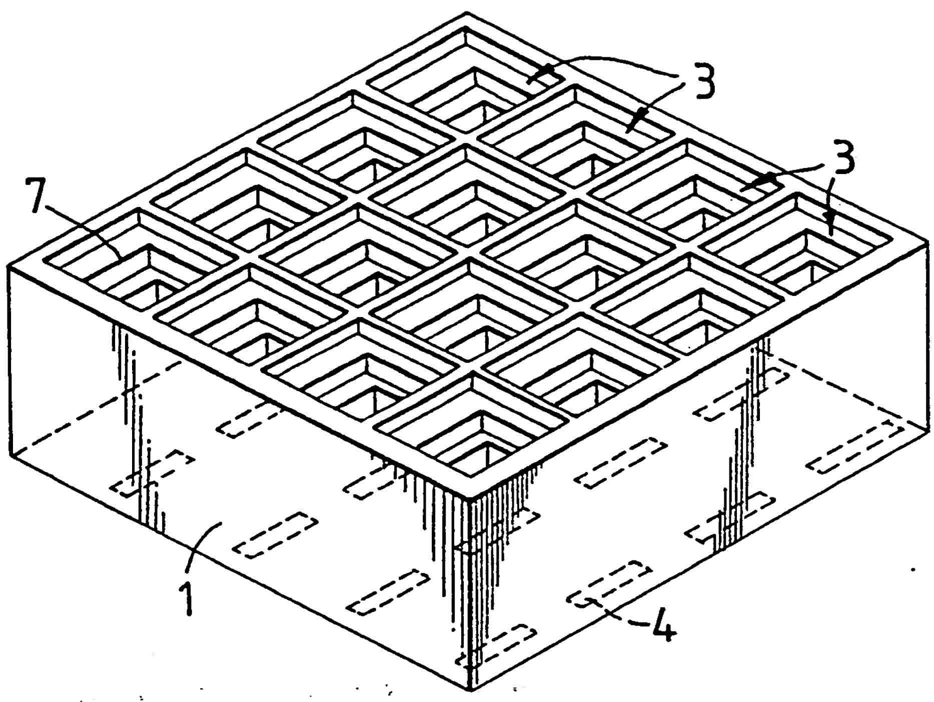
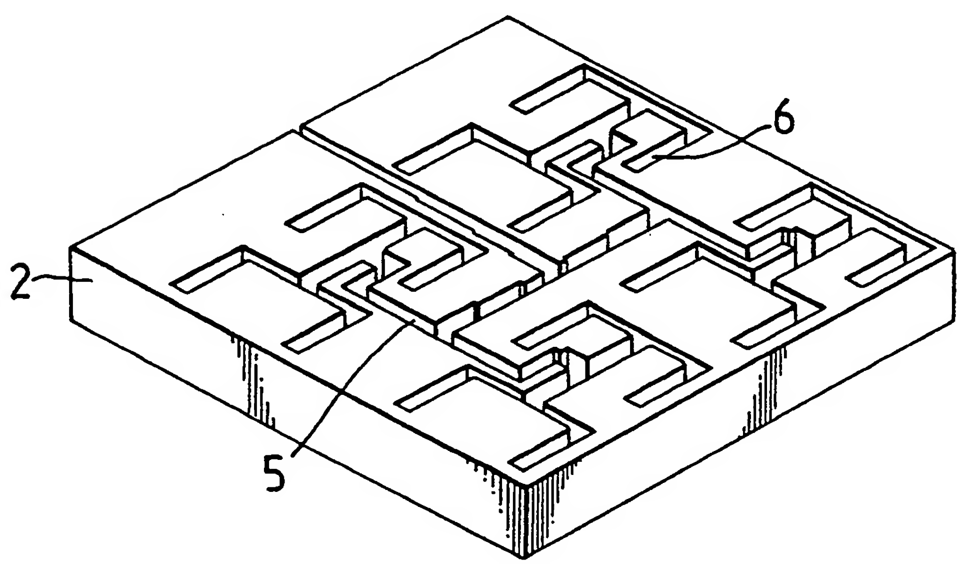


FIG.1.



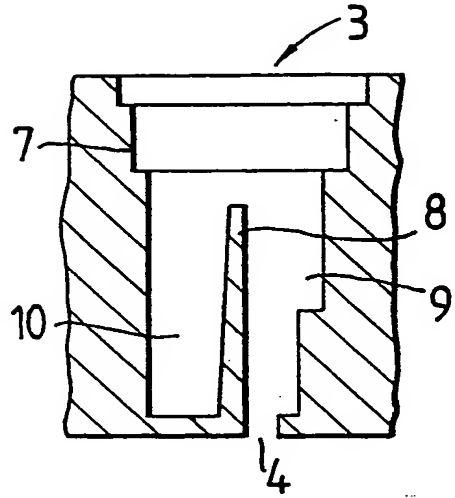


FIG.2.

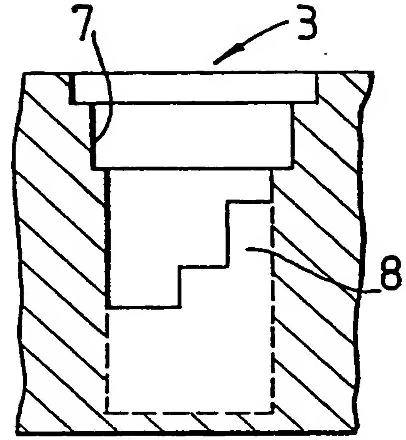


FIG. 3.

FIG.4.

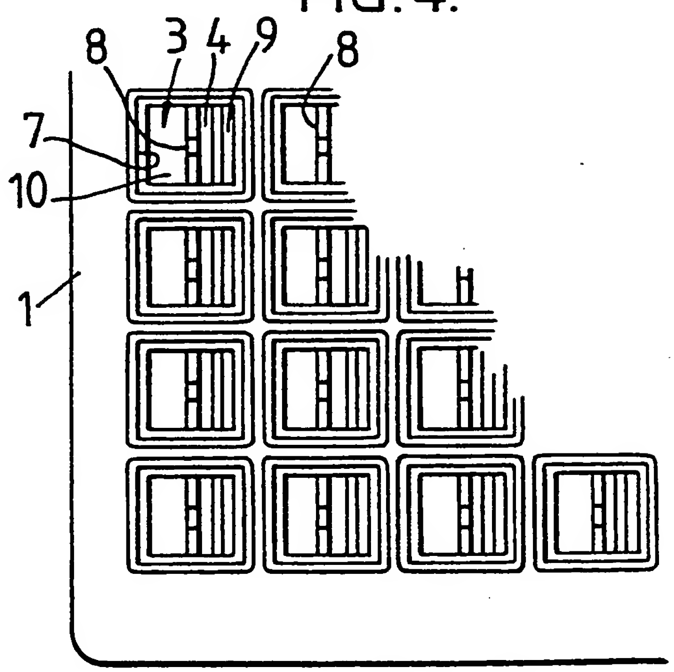


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FIG. 5.

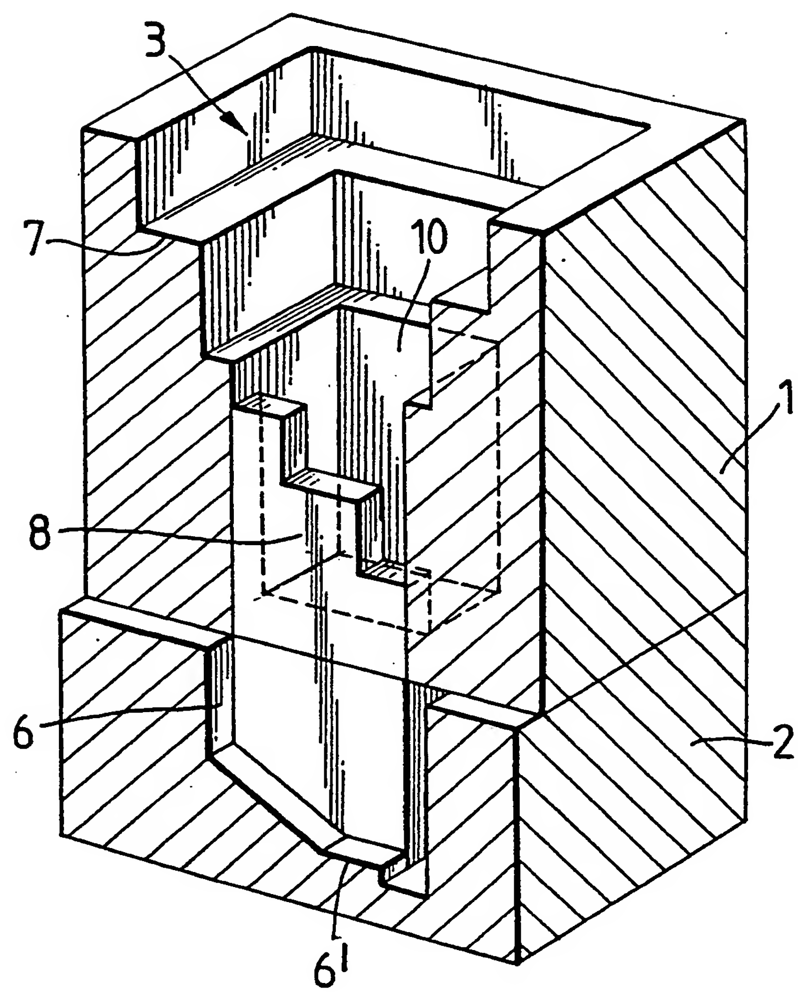
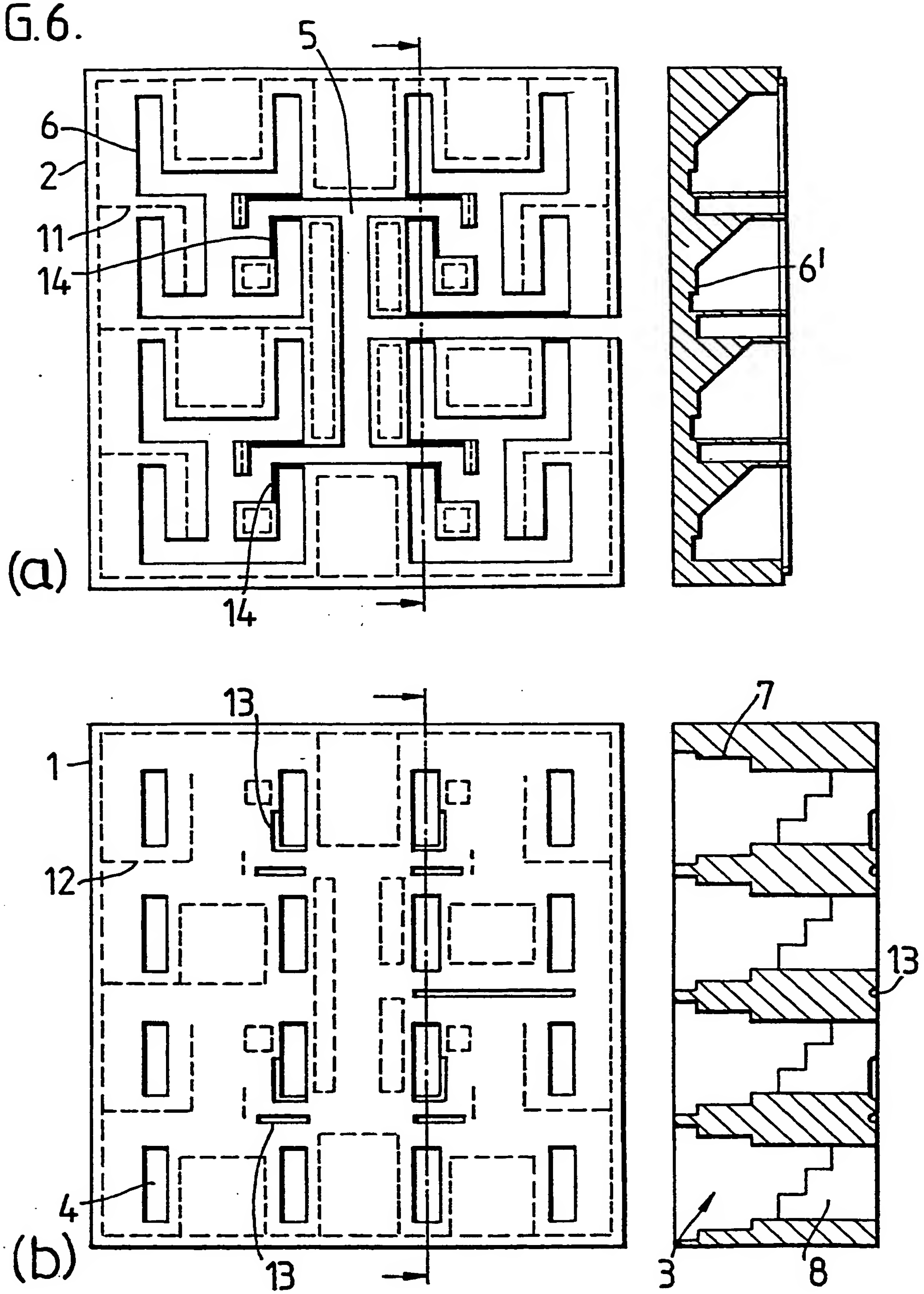


FIG.6.



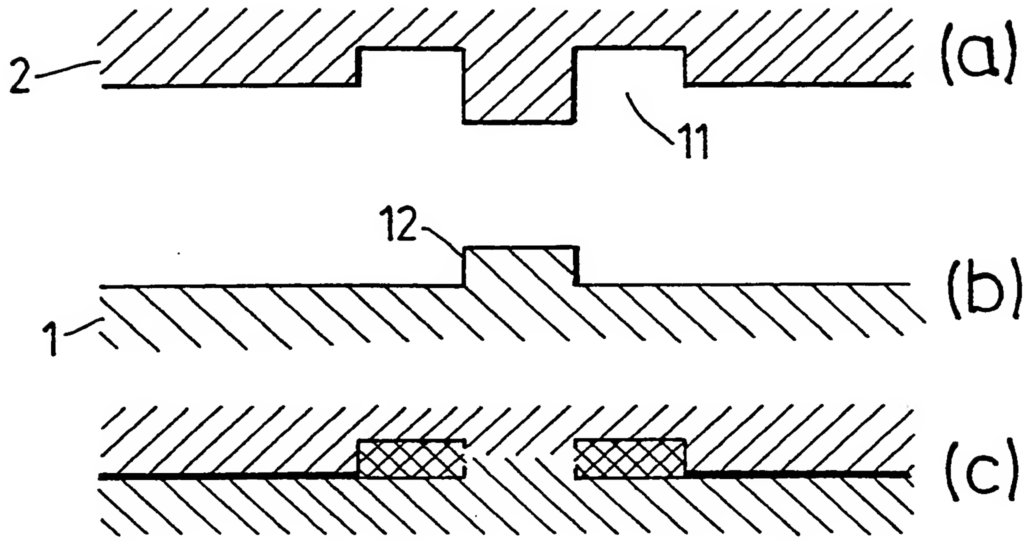


FIG.7

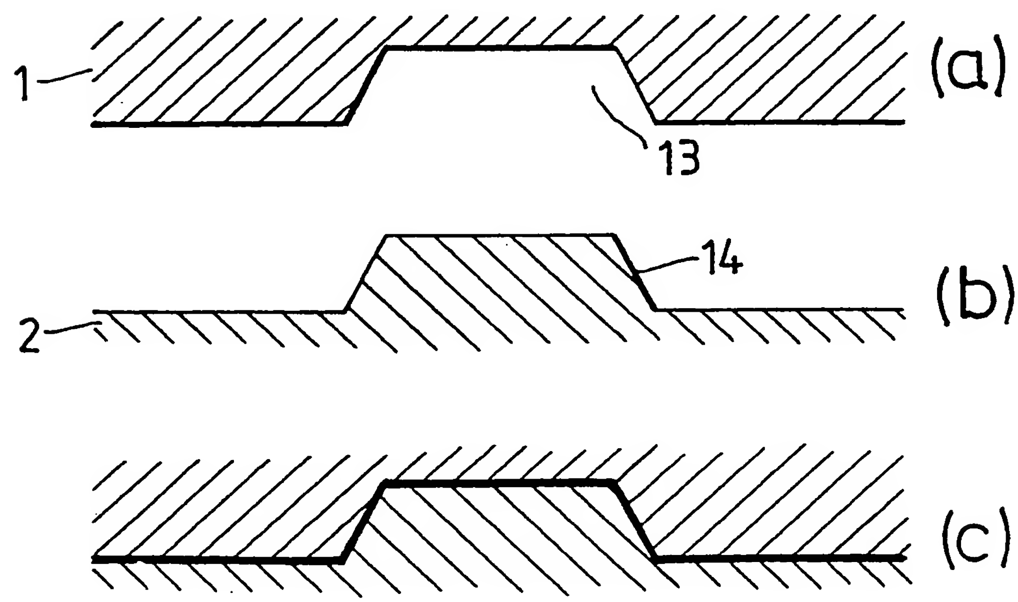


FIG.8.

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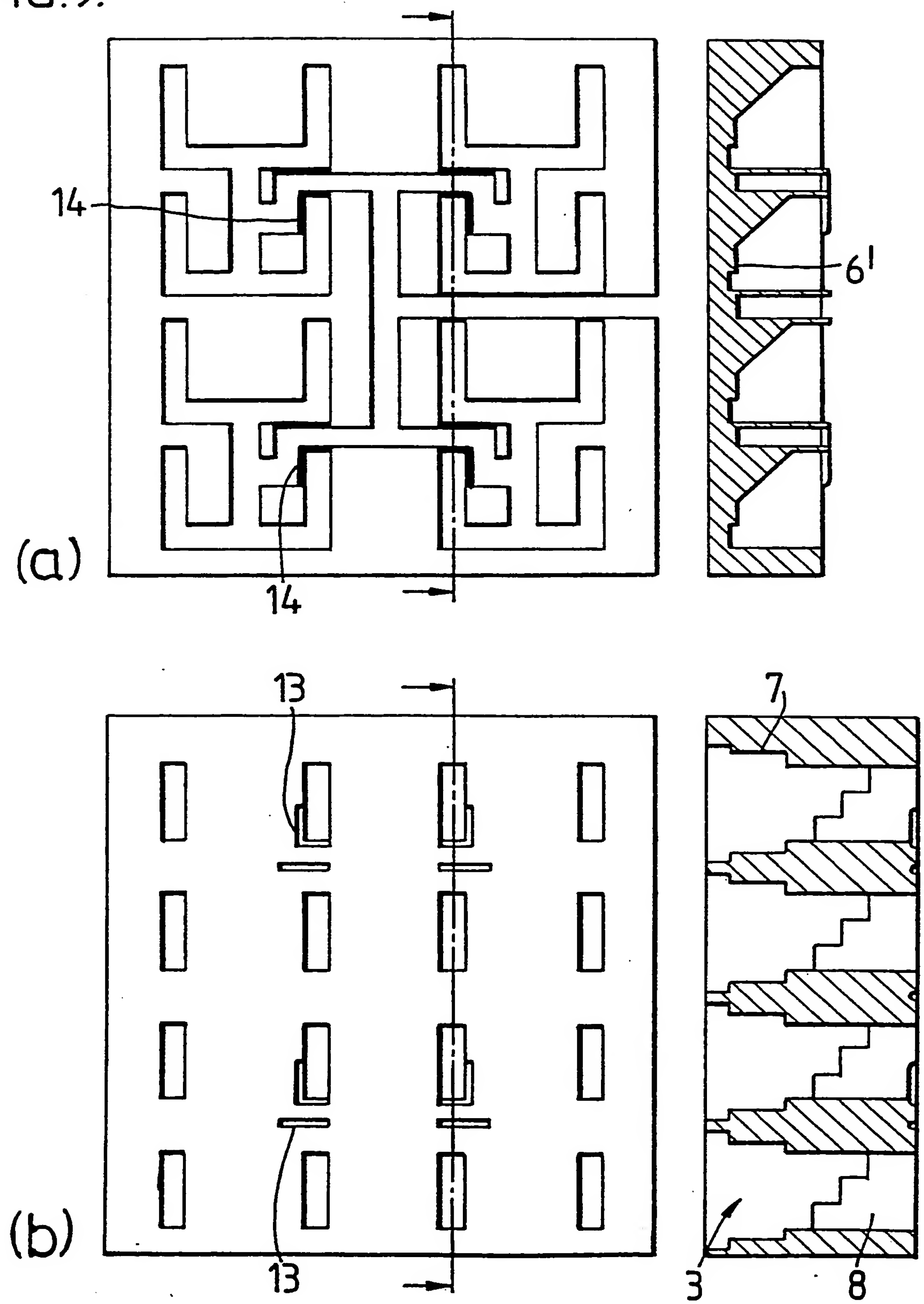
FIG. 9.



ANTENNAS AND METHOD OF MANUFACTURING THEREOF

The present invention relates generally to antennas and more specifically to flat plate antennas, such as those suitable for reception or transmission of circularly or linearly polarised high-frequency signals.

The recent increase in demand for flat plate antennas for reception of satellite broadcast television programmes has led to proposals for the development of mass-produced plastics antennas. Such antennas are manufactured by attaching together a series of metallised plastics plates to form the desired antenna structure.

However, such antennas suffer from the disadvantage that the mating surfaces of the individual plastics plates are not sufficiently flat without further processing, such as machining, to prevent leakage of microwave radiation if the plates are directly attached to each other. Consequently, it has been proposed (see WO 89/09501) to incorporate a thin layer, or shim, of metal between two adjacent plates in the antenna structure so as to compensate for the unevenness of the opposed surfaces. Even with such a metallic shim, there is still the possibility

of a small amount of microwave radiation leakage.

It would therefore be desirable to provide a method of manufacturing a flat plate antenna wherein the leakage of microwave radiation is further reduced and/or the need for a shim is avoided.

According to a first aspect of the present invention there is provided a method of manufacturing a flat plate antenna comprising attaching together (preferably by welding) two plates at least one of which is formed with a recessed pattern such that, when attached, the plates have formed therein a waveguide structure, and subsequently coating said structure with metal.

The metal of the coating is preferably copper for reasons of cost and ease of volume production. However, aluminium or silver could alternatively be used.

By providing the metal coating after the plates have been attached together, an antenna can be satisfactorily manufactured without requiring a metal shim to be provided between adjacent plates, thereby simplifying the structure of the antenna and substantially reducing costs. However, a shim may still be provided if desired, the step of metallising after attachment of the plates having the advantage of further reducing the leakage of microwave radiation.

According to a second aspect of the present invention there is provided a method of manufacturing a flat plate antenna comprising directly attaching together a first integrally formed plate and a second integrally formed plate, said plates being configured to define a plurality of horns, said second plate having an open-sided channel which is closed by said first plate to form a waveguide. Thus, no shim is provided between the plates.

The invention further extends to a flat plate antenna manufactured by any of the methods of the invention and to an antenna array comprising a plurality of such flat plate antennas arranged side-by-side.

The plates are preferably formed from structural foam. By "structural foam" is meant any moulding, whether plastics or metal, which can be regarded as structural and cellular in form. Thus this term is intended to include most rigid injection-moulded polyurethane components and includes, for example, thermoplastics injected in a molten state into a closed mould. By using structural foam, the resulting antenna is, in the preferred case of plastics material, lightweight and relatively inexpensive to manufacture, and less subject to deformation during moulding.

In a previously proposed antenna structure, one of the plates has coring in the form of a series of channels recessed therein which at least partially overlie the waveguide recesses in the lower plate. A shim is thus needed for closing the waveguide recesses to complete the waveguide structure. The purpose of the channels is not only to reduce the weight of the antenna, but also to reduce the thickness of the moulded plastic, since the moulding of thick sections of plastic can result in a somewhat deformed structure. However, by using structural foam, which exhibits less deformation, the coring can be avoided or reduced, so that no problems arise from omitting the shim. In this case the small amount of deformation can readily be compensated for by metallisation subsequent to attachment of the plates.

It will be appreciated that, in a preferred embodiment of the invention, an efficient and inexpensive antenna can be constructed without the need for a shim; microwave losses are reduced both by reducing deformation (because structural foam is used) and minimising losses caused by any remaining irregularities (because of the step of metallising after assembly), while weight increases resulting from no longer providing coring are balanced by using the lighter structural foam.

In accordance with a third aspect of the invention a flat plate antenna comprises at least two plates which are so configured, that when the plates are attached together, they define a waveguide structure which terminates in horns, the plates having been attached together by welding. Heat welding or solvent welding may be used. It has been found that the welding of the plates connects them together in a more intimate fashion, thus reducing microwave leakage.

In order that the present invention may be better understood a detailed description of preferred embodiments of the present invention will now be described with reference to the accompanying drawings, wherein:

Figure 1 shows an isometric view of the two plates of a flat plate antenna in accordance with the present invention;

Figures 2 and 3 show perpendicular cross-sectional views of one of the horns in the horn plate, this being the upper plate shown in Figure 1;

Figure 4 shows in plan view the horn plate;

Figure 5 shows a cross-sectional isometric view of part of a single horn element when attached to its corresponding part of the waveguide plate;

Figure 6 shows in both plan and cross-sectional

view the mating surfaces of the plates indicating the positions of tongues and grooves and ribs and troughs;

Figure 7 shows in cross-section the trough and groove arrangement of Figure 6;

Figure 8 shows a tongue and groove arrangement used to assist in attaching the two plates together; and

Figure 9 shows in both plan and cross-sectional view the mating surfaces of the two plates indicating the positions of the tongues and grooves.

With reference to Figure 1 there are shown an upper, horn plate 1 and a lower, waveguide plate 2. The horn plate 1 consists of an array of stepped horns 3 each of which extends from a large square cross-sectioned aperture on the upper surface of the plate 1 to a relatively small elongate aperture 4 on the underside of the plate. The waveguide plate 2 is formed with a recessed pattern 5 which constitutes the major part of a waveguide for transmitting microwave radiation received by the horn elements of the upper plate 1. When the two plates are attached together the apertures 4 in the lower surface of the upper plate 1 are aligned with corresponding arms 6 of the waveguide structure.

The shape of the horn elements 3 is indicated in

more detail in Figures 2 and 3. It can be seen that each horn element comprises a stepped wall 7 extending in square-shape cross-section from the upper surface of the horn plate to the lower surface ending in the aperture 4. A septum polariser 8 is provided in the central region of each horn element which divides the horn into a receiving channel 9 and a reflecting channel 10. The polariser serves to convert incoming circularly polarised radiation to linearly polarised and outgoing linearly polarised radiation to circularly polarised. Thus in an antenna arranged to receive or transmit linearly polarised signals, the polariser would be omitted from the structure. The polariser has a stepped configuration, as shown in Figure 3.

Figure 4 shows a plan view of the horn plate 1 viewed from above, indicating the position of the septum polariser 8 within each horn element 3.

When the two plates 1, 2 are attached together, the relative position of each horn element 3 and its corresponding waveguide arm 6 is as shown in Figure 5. It can be seen that this Figure is in the form of a staggered cross-section, the plane of the cut in the horn element being parallel to, but not coincident with, the plane of the cut of the waveguide plate 2. The waveguide arm 6 is provided with a stepped portion

6' in order that the received signal propagates in a more efficient manner.

In a first embodiment the horn plate 1 and waveguide plate 2 are attached together by heat welding. In this case, the upper, mating, surface of the waveguide plate 2 is moulded with a pattern of troughs 11 within each of which is located a rib. A corresponding pattern of ribs 12 is moulded on the lower, mating, surface of the horn plate 1. These patterns are indicated in Figure 6 in phantom. The cross-sectional form of the troughs and ribs is indicated in Figure 7 wherein cross-section (a) indicates the rib and trough formation of the horn plate 1 and cross-section (b) indicates the rib formation of the waveguide plate 2. Immediately prior to attachment, the two mating surfaces of the plates are heated by placing a heating element between the two plates. When the mating surfaces have become sufficiently heated, the heating element is removed. The ribs of the waveguide plate 2 are then brought into abutment with the ribs of the horn plate 1 and the two plates are clamped together under pressure, while the mating surfaces are still plastic, which causes the material within the two ribs to flow into the recesses within the trough formation 11. Figure 7(c) indicates the relative positions of the two

plates after heat welding, and it can be seen that, after all of the material from the ribs has been caused to flow into the recesses, the main mating surfaces of the two plates are in abutment.

In order to prevent the thin-walled portions of the waveguide plate becoming eroded during heat welding and also to assist in accurate relative positioning of the two plates, these portions are provided with a pattern of tongues 14 which extend above the interfacial plane of the two plates and which mate with a corresponding pattern of grooves 13 in the lower surface of the horn plate 1. The cross-sectional form of a groove and corresponding tongue is shown in Figure 8(a) and (b). When the two plates are attached together, it can be seen from Figure 8(c) that the main mating surfaces of the two plates are brought into abutment, the tongue mating with the corresponding groove. The positions of the tongues in the waveguide plate is indicated by solid shading in Figure 6(a), with the corresponding grooves in the horn plate 1 being indicated in the corresponding positions in Figure 6(b). As with the ribs and troughs, the tongues and grooves are formed during moulding of the plates.

In a second embodiment the upper and lower plates are attached together by means of solvent welding. In

this case, the rib and trough formations shown in Figure 7 are omitted, the plates merely being provided with the tongue and groove formations shown in Figure 8. These are located in the same positions in the corresponding plates as in the plates designed for heat welding and serve to prevent solvent erosion of the thin-walled portions of the waveguide plate. Figure 9 indicates these positions, and it can be seen that the rib and trough formations 11 and 12 of Figure 6 are not present.

To achieve solvent welding the mating surface of each plate is brushed with dichloromethane, and the two mating surfaces are clamped together under pressure.

Alternatively, other means of attachment may be used such as, for example, bolting of the two plates together or heat-staking. In the latter case one of the two plates is provided with a pattern of projecting pins which are caused to mate with corresponding apertures in the other plate. The application of heat to the interface of the two plates causes the two plates to become attached together. However, heat and solvent welding are preferred, since lower mechanical forces are involved.

After the two plates have become attached together, an antenna array is formed by joining

together nine such structures side-by-side in a three-by-three array. As can be seen in e.g. Figure 1, each structure comprises a four-by-four array of horn elements. An array of nine such structures therefore comprises an complete antenna array of twelve-by-twelve horn elements, this being 30 cm wide.

The array is then immersed in an electroless copper plating bath, such that all exposed surfaces of the array become coated with a thin copper film of approximately 4 microns in thickness. By performing the copper plating after the attachment of the plates, any slight imperfection in the flatness of the two mating surfaces of the plates which could give rise to leakage of microwave radiation are caused to be coated with the copper, thereby reducing substantially such leakage.

Clearly, each four-by-four array antenna structure can serve as a complete antenna. However, it may be desirable in certain circumstances to fabricate a larger antenna. This can be done either by joining such four-by-four arrays together, as above, or by fabricating a larger antenna directly from two correspondingly larger upper and lower plates.

In the preferred embodiments the horn plate 1 and the waveguide plate 2 are formed from structural foam

which has the advantage that relatively thick sections of material can be moulded without suffering subsequent deformation.

As a result of the above features, an antenna structure can be fabricated without requiring the provision of a metal shim between the two plates. However, a copper shim can still be introduced into such a structure, but, in this case, it is preferred that the two plates are heat welded together. Such a shim is provided with apertures corresponding in size and position to the apertures in the lower surface of the horn plate to enable radiation received by the horn array to pass into the waveguide. The shim would be located within the area defined by the outermost rib of the plates (see Figure 6(a)), the remainder of the rib pattern being omitted. The mating surfaces of the horn plate 1 and waveguide plate 2 would consequently be provided only with the outer rib and trough pattern. As mentioned earlier, if a shim is provided, it is possible to provide a series of channels in the lower surface of the horn plate, resulting in a lightweight, and also cheaper structure. Furthermore, such a structure involves thinner walls in the horn plate and is therefore less subject to deformation on moulding.

Whether or not such a shim is provided, the

benefit of copper plating of the structure subsequent to attachment together of the two plates still remains, namely that any slight imperfection in the mating surfaces is effectively compensated for by the copper plating.

As mentioned earlier, silver or aluminium could alternatively be used to plate the antenna structure.

The septum polariser may be replaced by a polariser placed in front of the antenna.

Furthermore, one or more additional waveguide plates may be incorporated into the antenna structure, each resulting waveguide being connected to the horns within the horn plate.

Numerous other modifications and improvements falling within the scope of the claims appended hereto will be apparent to those skilled in the art, and the invention is not to be considered in any way limited to the specific embodiments described above.

CLAIMS:

1. A method of manufacturing a flat plate antenna comprising attaching together two plates at least one of which is formed with a recessed pattern such that, when attached, the plates have formed therein a waveguide structure, and subsequently coating said structure with metal.

2. A method of manufacturing a flat plate antenna comprising directly attaching together a first integrally formed plate and a second integrally formed plate, said plates being configured to define a plurality of horns, said second plate having an open-sided channel which is closed by said first plate to form a waveguide.

3. A method as claimed in claim 1 or claim 2, wherein said plates are formed from plastics material.

4. A method as claimed in any preceding claim, wherein said plates are formed of structural foam.

5. A method as claimed in claim 2, or claim 3 or 4, when directly or indirectly appendant to claim 2,

further comprising the step of coating said plates with metal subsequent to the attachment together thereof.

6. A method as claimed in claim 1 or 5, wherein said metal is copper.

7. A method as claimed in claim 5 or 6, wherein said plates are coated with said metal by electroless deposition.

8. A method as claimed in any preceding claim, further comprising forming a plurality of grooves in one of said plates and forming a plurality of corresponding tongues on the other of said plates which tongues mate with said grooves when the two plates are attached together.

9. A method as claimed in claim 8, wherein said tongues are formed on thin-walled plate portions defining a waveguide structure.

10. A method as claimed in any preceding claim, wherein said plates are attached together by heat welding.

11. A method as claimed in claim 10, further comprising the step of forming a plurality of troughs in one of said plates and a plurality of ribs in the other of said plates corresponding in number and position to said plurality of troughs.

12. A method as claimed in claim 11, further comprising the step of forming a rib in each of said plurality of troughs and, prior to the step of heat welding, causing each rib in said one plate to abut the corresponding rib in said other plate, whereby, on heat welding, the material from the ribs of both plates is at least partially accommodated in said troughs.

13. A method as claimed in any one claims 1 to 9, wherein said plates are attached together by solvent welding.

14. A method as claimed in claim 13, wherein the solvent used is dichloromethane.

15. A method of manufacturing a flat plate antenna comprising attaching together at least two plates which are so configured that, when attached, they define a waveguide structure terminating in

horns, wherein the plates are attached together by welding.

16. A flat plate antenna manufactured by a method as claimed in any one of claims 1 to 15.

17. An antenna array comprising a plurality of flat plate antennas each as claimed in claim 16 arranged side-by-side.

18. A method of manufacturing a flat plate antenna substantially as hereinbefore described with reference to the accompanying drawings.

19. A flat plate antenna substantially as hereinbefore described with reference to the accompanying drawings.

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